DETERMINANTS OF ADOPTION OF RAINWATER MANAGEMENT PRACTICES IN THE NILE BASIN

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1. Introduction

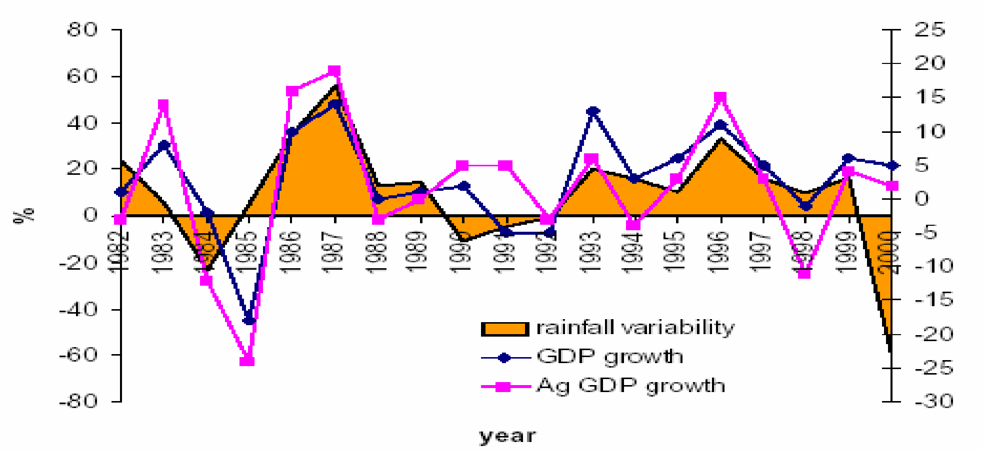
Water scarcity and land degradation affects the livelihoods of people in Sub-Saharan Africa (SSA). Despite that about 70 to 90 percent of the total water withdrawal in this region is used by agriculture (ILRI and IWMI, 2010), studies indicate that Africa's agriculture in general and that of SSA in particular is negatively affected by climate change (Pearce et al. 1996; McCarthy et al. 2001). Rainfall distribution is extremely uneven both spatially and temporally and has negative implications for the livelihood of the population (FAO, 2005). The region faces widespread poverty and food insecurity where lack of human, economic and institutional capacities to effectively develop and manage water resources affect the sustainable use of water resources. Furthermore, high population growth, poverty and underdevelopment are the key drivers that affect how agricultural water is managed in the Sub-Saharan Africa (WWAP, 2012). Besides, to use of the available water potential, the need to improve water productivity and land degradation is paramount importance. The key issues are, therefore, investing in the potential of water resources to produce enough food and effectively manage land degradation, droughts, floods and desertification (NEPAD, 2006) where rainwater management (RWH) is one of the technological options to improve access to water for agricultural production and environmental sustainability (D. Baguma, et al. 2010). RWH is generally defined as a method of runoff collection for agriculture, such as crop, fodder, pasture/tree production, livestock and domestic water supply (Ngigi, 2003; Ncube et al., 2008; Boers and Ben-Asher, 1982). RWH may lead to increased infiltration and groundwater recharge with downstream impacts (both positive and negative impact). In line with this, RWH have received considerable attention in SSA in the 1970s and 1980s mainly due to recurrent droughts that have resulted in widespread crop failures (Hatibu et al, 2004). Since then, a number of RWH projects were implemented to rehabilitate degraded land

and improve food security (Critchley and Reij, 1989; Critchley, 1991). For example, countries such as Zimbabwe, Kenya, Swaziland, Ethiopia and Tanzania introduced RWH techniques to improve the productivity of smallholder farmers (Motsi et al, 2003; Kidundo et al, 1997).

Agriculture, Climate Change and Rainwater Management Practices in Ethiopia

Agriculture is the main sector of the Ethiopian economy. It contributes about 42% of the GDP, generates more than 85% of the foreign exchange earnings and employs about 80% of the population (CSA, 2004, MoFED, 2004). Despite its role, this sector is constrained by climate-related adversities like drought often causing widespread crop failure and poverty (Deressa, 2007). The trend of climate is characterized by extremes, such as drought and flood increasing temperature and decreasing precipitation trends. Studies indicate that temperature and precipitation have been changing over time leading to frequent prevalence of drought, especially in the lowlands (Lautze et al. 2003; NMS 2007). Average annual rainfall is highly variable (NMS 2007) that result in droughts and reduced agricultural production and food insecurity. The performance of agriculture and its contribution to total GDP is highly dependent on the trend of rainfall and rainfall variability. As presented in Figure 1, the contribution of agriculture to GDP and the performance of GDP in general is tagged with the trend of rainfall implying that the economy perform well in years of good rainfall and the reverse is true.

Figure 1: Rainfall variation and GDP growth



Source: World Bank (2006)

As part of the Ethiopian climate extremes, intense precipitation that results in low infiltration and high runoff causes soil erosion and land degradation also resulted in declined agricultural productivity. Soil erosion, nutrient depletion and deforestation are common environmental problems in the Ethiopian highlands in general and in the Blue Nile Basin in particular (Hagos, et al. 1999). According to Hydosult et al. (2006), for example, the steep slopes in East and West Gojam; North and East of the Abay River; the upper Jema sub-basin in South Wello; the high hills of North and West of Debre Birhan; and the upper and middle steep slopes of the Middle Abay in East Wellega are among the high sheet erosion areas in the Nile (Abay) basin. These areas are characterized by steep cultivated slopes and high rainfall intensity causing severe soil erosion hazards. Furthermore, two subsidiary areas with high erosion hazards can be found in the upper Didessa, Dinder and Beles valleys (Hagos, et al. 2008).

Moreover, poor land management practices and lack of effective rainwater management strategies aggravates poverty and environmental fragility. The problem is serious in the highland areas which is home for about 44% of the country's total area, 95% of the cultivated area, about

88% of the human population and two-third of the country's livestock population (Kruger et al., 1996). Although estimates are not consistent, different studies hint that about 3.7% of the highlands had been seriously eroded while about 52% of it had suffered various levels of degradation (Kruger et al., 1996; Wood, 1990). In general poor land management practices and lack of effective rainwater management (RWM) technologies have worsen the situation.

In response to the problems, a range of conservation measures including stone terraces, soil bunds and area closures; have been practiced in massive scales, although the trend shows that the projects have had a limited success. Since the early 1970s for example, food for work (FFW) programs was implemented aligning them with soil and water conservation (SWC) activities. The program has been used as a means to provide much-needed food aid to rural people, while requiring them to work on SWC programs to reverse soil erosion and land degradation (Merrey, D.J. and Gebreselassie, T., 2011). Recent programs including rainwater harvesting ponds, shallow wells, and river diversion structures, biological as well as physical land management structures associated with income-generating activities got emphasis (ibid). Zemadim et al., (2011) documented that runoff farming practices which are closely related to SWC program targets reducing soil erosion with little or no interest in enhancing soil water infiltration.

However, the outcome of conservation measures was not as expected implying that interventions should focus not only on the engineering and biophysical performance of conservation measures, but also on socio-economic and livelihood benefits. Studies from the Ethiopian highlands (Amsalu) show that the adoption and scaling-up of rainwater management technologies are influenced by a variety of factors including bio-physical characteristics, such as topography, slope, soil fertility, rainfall and rainfall variability (Deressa et al., 2009). Experience also show that even technologies are appropriate, they are not always adopted (Guerin, 1999), because

farmers may reject or abandon them since farmers consider a variety of factors in their decision of adoption (McDonald and Brown, 2000; Soule et al., 2000). Moreover, farmers rarely sustain externally driven technical solutions unless consideration is given to socio-economic, cultural and institutional, as well as biophysical and technical factors (McDonald and Brown, 2000; Merrey, D.J. and Gebreselassie, T., 2011). However, there is no agreement on factors that affect the adoption of specific technologies and practices mainly due to high degree of locational and technological specificity. This demands a better understanding of factors that encourage or discourage adoption of technologies or practices, which can be farm and/or technology-specific. According to Lapar and Pandey (1999), for example, adoption of conservation practices in the Philippines depend on several plot and farmer characteristics where the relative importance of these factors differs across sites. On the other hand, Guerin (1999) noted access to extension service as an important factor for the adoption of technologies, while Smit and Smithers (1992) give emphasis to the nature and characteristics of the innovation being relevant.

Empirical study from the Nile Basin (Deressa et al., 2009) indicated that among others, level of education; gender (being male of household head); age; farm and non-farm income, wealth of the household, access to extension and credit; information on climate; farmer to farmer extension and number of relatives (as a proxy of social capital) influence farmers' adoption of RWM technologies. Deressa, et al. (2008) also identified that lack of information, lack of capital, shortage of labor, shortage of land, and poor potential for irrigation are the five major barriers to adapt to climate change. An agro-ecological setting also affects farmers' choice of technologies implying that farmers living in different agro-ecological locations use different adaptation

methods. For instance, farming in the kola[1] zone significantly increases the probability of soil conservation and reduces the probability of using different crop varieties, planting trees, and irrigation compared to farming in weynadega[2] (ibid). Despite that a blanket approach of rainwater management strategies are often inappropriate, existing efforts does not seem to consider these. Moreover, relatively little empirical work has been done to examine factors that affect the adoption of RWM technologies at watershed level. Most of past research focused on the adoption of SWC at large (country or regional) scale, while farmers typically adopt multiple RWM technologies as substitutes or supplements that deal with their overlapping constraints and suitable to specific landscapes. Since suitability of RWH technologies can possibly depend on landscape position, strategies in upper slopes are likely to be different from those in lower slopes. In such scenario, analysis made without controlling for landscape/watershed variability may underestimate or overestimate the influence of factors on the adoption and scaling-up of rainwater management technologies.

Hence, one way to improve productivity and climate change resilient livelihoods in the Ethiopian highlands is to target promising technologies that better suits a particular environment. This helps to overcome the limited success and impact of practices that often adopted using ‘blanket’ approaches (ILRI and IWMI, 2010). The objective of this study is, therefore, to understand factors that favors or disfavor the adoption and scaling-up of particular sets of rainwater management practices in the Blue Nile basin. We also aim to understand why farmers do not adopt some rainwater management strategies despite their suitability and potential benefits. The outcome of this study will contribute to the growing evidences on RWM technologies as a

[1] Kola is a traditional term agroclimatic zones where altitude, average annual temperature and average annual rainfall is: 500 – 1,500 masl, 27.5 – 20.0 C0, and 200 – 800 mm, respectively (Deressa, et al., 2008).

[2] Weynadega is a traditional agroclimatic zones where altitude, average annual temperature and average annual rainfall is: 1,500 – 2,300 masl, 20.0–17.5/16.0 C0, and 800 – 1,200mm, respectively (Deressa, et al., 2008)

strategy for sustainable agriculture and climate change resilient livelihoods. Moreover, its contribution towards informed policy making in targeting rainwater management technologies is significant.

2. Study Area and Data

This study is based on cross-sectional household survey data from the Blue Nile Basin of Ethiopia. The International Water Management Institute (IWMI) in collaboration with the International Livestock Research Institute (ILRI) and national partners (including Amhara Agricultural Research Institute (ARARI, Oromia Agricultural Research Institute (ORARI) and Ethiopian Rainwater Management Association (ERHA)) has collected data from 654 randomly selected sample households from seven watersheds (see Table 1). The sample watersheds include the three NBDC sites and four other new watersheds in the Blue Nile Basin. The four new sites (watersheds) have been selected by OARI (Oromia agricultural research institute) and ARARI (Amhara regional agricultural research institute). Criteria used to select the new sites (watersheds) include presence of modeled practices, having watershed with strong NGO intervention and watershed with little NGO intervention, size and slope of the watershed (i.e. the watershed should be relatively small manageable by one or two communities and therefore fit our concept of landscape within a short distance) and existing connection through OARI and ARARI.

Table 1: Surveyed watersheds and number of sample households

Region	District	Watershed	Site	Number of sample households	Collected by
Oromia	Jeldu	Meja	N2	120	ERHA
	Guder	Boke	New	90	ORARI
	Shambu	Laku	New	90	ORARI
	Diga	Diga	N2	90	ORARI
Amhara	Farta	Zefe	New	90	ARARI
	Fogera	Mizuwa	N2	101	ARARI
	Gondar Zuria	Gumera/Maksinit	New	90	ARARI
Total				671	

Rainwater management technologies considered in this study includes bunds/terraces (with and without vegetation), multipurpose trees, orchard, shallow/hand-dug wells, water harvesting ponds, river diversion, area enclosure and gully rehabilitation/check dams. A multi-stage stratified random sampling procedure was used to select sample households. First, we use the list of households in each kebele/community where the watershed exists and then we stratified them by landscape location. In the second stage, households in the selected landscape were stratified into female and male headed households and situates of adoption as adopter and non-adopter. Such strategy helps us to get a reasonable proportion of female and male headed as well as adopter and non-adopter households that give us an option for counterfactual analysis. Finally, a proportional random sampling was employed to get the 671 sample households. However, once data was collected, we noticed that 17 households from Meja watershed in Jeldu were wrongly surveyed. We dropped these households from the data set and use only 654 sample households.

A structured questionnaire was prepared and data was collected under close supervision of researchers from partner institutions (i.e., IWMI, ILRI ARARI, ORARI and ERHA). The questionnaire has consisted detailed enquiries about household, plot and community level data including access to input and market, households' family composition, education, asset

ownership, sources of income, participation in credit markets, membership in formal and informal organizations, access to extension services, adoption of rainwater management technologies and crop-livestock production. Initially, we planned to study nine rainwater management practices/technologies, but the adoption rate of shallow/hand-dug wells and ponds were found very low and insufficient for statistical analysis (see Table 2) for which reason we have dropped these technologies in our analysis.

Table 2 presents the number of household heads that have adopted rainwater management technologies/practices. Bunds/terraces (without vegetation) followed by gully rehabilitation; multipurpose trees; area enclosure; river diversion; orchards; Bunds/terraces (with vegetation); shallow/hand-dug well and pond is the most adopted rainwater management technology, respectively. Zefi, Gumera/Meksinit and Mizwa watersheds, all in Amhara region were found with high adoption rate of rainwater management technologies, probably influenced by differences in rainfall pattern, bio-physical and socio-economic characteristics of the areas (watersheds) that worth investigation in this paper. Zemadim et al. (2011) indicted that there are successful stories of RWM programs as part of the sustainable land management (SLM) project to increase in-situ water availability and increase aquifer recharge mainly in Amhara, Oromiya, Tigray and Somali regions. On the other hand, despite massive investments have been made in rainwater management technologies such as ponds, the adoption rate is minimal, possibly due to their low rate of success. This is consistent with the finding of a study by Arbaminch University (AMU, 2009). AMU (2009) has documented that most of the 40,000 RWH ponds constructed between 2003 and 2008 in Amhara and Tigray regions of Ethiopia have failed, generally due to lack of monitoring after their construction leading to farmers' lack of confidence to invest in this technology.

Table 2: Adoption rate of rainwater management technologies by watershed.

RWH Technology	Watersheds							Total
	Meja	Zefi	Gumera/Meksinit	Boke	Diga	Laku	Mizwa	
Multipurpose Trees	37	18	16	52	52	45	15	235
Orchards	9	25	6	2	32	12	10	96
Bunds/Terraces(without Vegetation)	28	77	77	65	75	70	85	477
Bunds/Terraces (with Vegetation)	19	26	21	6	5	4	9	90
Shallow/hand-dug well	16	9	1	1	0	4	1	32
Pond	10	3	2	1	0	2	5	23
River diversion	24	12	11	16	7	12	28	110
Enclosure	17	41	42	5	0	1	15	121
Gully rehabilitation	26	72	71	30	14	27	57	297
Total	186	283	247	178	185	177	225	1481

In many parts of the Ethiopian highlands, farmers have been practicing rainwater management technologies, such as bund/terraces to preserve the top soil, so that they can have sustainable cultivation of crops for their sustenance. Bunding and terracing is accompanied by drainage, but it is rarely done. Slope is a major factor in determining whether bunds or terraces should be constructed for soil conservation in a given place. Terraces are usually found on medium to steep slopes and can be made by moving soil from one place to another on the slope and demand a lot of work. For example, about 1500 person days is required to terrace a single hectare on a steep slope. Data in Table 1 shows that bunds/terraces (without vegetation) were practiced by about 70.4% of the sample households.

Multipurpose trees are part of the RWM strategies. Farmers adopt this technology for soil and water conservation adn fuel wood. Despite many organizations in Ethiopia have promoted multipurpose fodder tree for livestock feed and soil improvement, however, the number of farmers practicing this technology remains low (A.K. Mekoya, 2008). About 32% of our sample households have adopted multipurpose trees, while about 54%, 47% and 46% of sample households in Boke, Laku and Diga watersheds, respectively, all from Oromia region have practiced multipurpose trees. Area enclosure and gully rehabilitation were adopted by about 17.6% of the total sample households, but these are more adopted in watersheds from Amhara side as compared to those from Oromia side. On the other hand, about 34.4% of sample households in Diga watershed have practiced orchards, while the least adopters of this technology are from Meja watershed.

3. Estimation Methods

We used both descriptive, such as graphs and summary statistics, and quantitative methods. Farmers are more likely to adopt a mix of rainwater management technologies as coping mechanisms to climate change and agricultural production constraints. These technologies may be adopted simultaneously and/or sequentially as complements, substitutes, or supplements of each other. For example, multipurpose trees are likely to complement bunds/terraces. Wile, adoption of bunds/terraces is likely to result in increased infiltration and ground/surface water recharge leading to adoption of shallow/hand-dug wells and then adoption of orchards and irrigated crops. When farmers adopt area enclosure and/or gully rehabilitation, they usually supplement it with different trees and grasses for animal feed and food production. Similarly, farmers usually invest in river diversion structures for irrigation to produce high value cash crops. This suggests that smallholder farmers face with alternative, but correlated technologies in

their adoption implying that technologies are not independent. Furthermore, the choice of technologies may be partly dependent on earlier expriences (M. Kassie et al., 2012). Some recent empirical studies (Moyo and Veeman 2004; Marenya and Barrett 2007; Nhemachena and Hassan 2007; Yu et al. 2008; Kassie et al. 2009) argue that farmers usually consider a set of possible technologies and try to select the one they assume can maximize their expected utility; hence the adoption decision is inherently multivariate. However, most of previous studies on technology adoption (such as rainwater management and conservation technologies) assume a single technology without considering the possible correlation (interdependence) between different technologies (Yu et al. 2008) that possibly mask the reality faced by decision-makers often faced by a set of choices. In general, when technologies are correlated, a univariate modeling excludes useful information contained in interdependence and simultaneous adoption decisions analysis, hence; a single technology approach may underestimate or overestimate the influences of various factors on the adoption decisions (Wu et al. 1998). Univariate probit models ignore the potential correlation among unobserved disturbances in the adoption equations, as well as the relationships between the adoptions of different rainwater management technologies, because farmers may consider some combination of technologies as complementary and/or competing. Hence, failure to capture such interdependence will lead to biased and inefficient estimates.

For this reason, we estimate multivariate probit (MVP) model as specified in M. Kassie et al. (2012; L. Cappellari and S. P. Jenkins, 2003) as follows.

$$Y_{ht}^{*} = \beta_t X_{ht}^{'} + \varepsilon_{ht}, \quad t = 1,....m \quad and \tag{1}$$

$$Y_{ht}^{*} = 1 \quad if \quad Y_{ht}^{*} > 0 \quad and \quad 0 \quad otherwise \tag{2}$$

Where $T = 1,...m$ represents the choices of rainwater management technologies in our case. The assumption is that h^{th} farm household has a latent variable, Y_{ht}^{*}, which captures the choices associated with the T^{th} rainwater management technology. The estimation is based on the observed binary discrete variables Y_{ht}^{*} that indicate whether or not h^{th} farm household has adopted a particular rainwater management technology (denoted by 1 for adoption and 0 for not adoption). The adoption status is assumed to be influenced by observed characteristics (X_{ht}) that include households' demographic characteristics, access to services, market, social capital (captured by household's membership in informal and/or formal social groups), and biophysical characteristics captured by woreda/district dummies. The unobserved characteristics are captured by the error term denoted by ε_{ht}, while β_t is a parameters to be estimated.

As discussed above, we assume that the rainwater management technologies considered in this paper are interdependent implying that adoption of one technology is likely to influence (positively or negatively) the likelihood of adoption of another technology, hence the error terms ($\varepsilon_{ht}, t = 1,...,m$) in Equation (1) are distributed as multivariate, each with zero mean and variance 1, where $\varepsilon_{ht} \approx MVN(0,V)$. The value of variance (V) is normalized to unity on the diagonal and correlations as off-diagonal elements. The non-zero value of the off-diagonal elements allow for correlation across the error terms of several latent equations, which represent unobserved characteristics that affect the choice of alternative rainwater management technologies (Kassie et al. 2012). The covariance matrix V is given by:

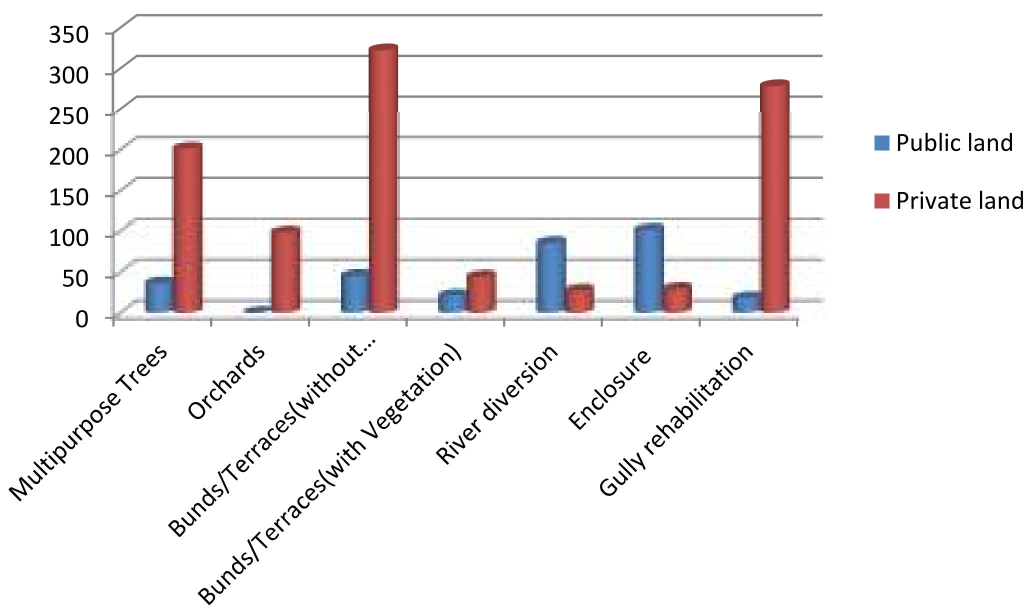
$$V = \begin{bmatrix} 1 & \rho_{12} & \rho_{13} & \cdots & \rho_{1m} \\ \rho_{21} & 1 & \rho_{23} & \cdots & \rho_{2m} \\ \rho_{31} & \rho_{33} & 1 & \cdots & \rho_{3m} \\ \vdots & \vdots & \vdots & 1 & \vdots \\ \rho_{m1} & \rho_{m2} & \rho_{m3} & & 1 \end{bmatrix} \quad (3)$$

In general, multivariate probit model is a generalization of the probit model that is used to estimate numerous correlated binary outcomes jointly (Wikipedia, the free encyclopedia at: http://en.wikipedia.org/wiki/Main_Page) where the source of correlation can be complementarity (positive correlation) and substitutability (negative correlation) between different technologies (Belderbos et al. 2004).

Initially, we have considered nine rainwater management technologies, but our survey data shows that the adoption rate of shallow well and pond was low (see Annex A1). The data is insignificant for statistical analysis for which reason we dropped both technologies in the analysis. Moreover, because estimation of multivariate probit with large technological choice (options) is cumbersome and difficult to converge, we merge similar technologies (i.e., bund/terraces with vegetation and bund/terraces without vegetation).

Finally, we review whether the technologies were adopted in private land or communal land and result show that most of households have adopted river diversion and area enclosure on communal lands (Figure 2), probably as collective action. Since our analysis is based on household level data, we also excluded both river diversion and area enclosure in the analysis.

Figure 2: Adoption of rainwater managementtechnologies and ownership of land



4. Independent Variables and Hypotheses

Explanatory variables considered in our regression analysis and their expected effects on adoption of rainwater management technologies are discussed below.

Household characteristics: In this regard, we considered different household characteristics and family member composition as proxy for households' human capital. For example, household head's education level, age, family size and gender are important indicators of households' human capital and influences adoption of technologies where rainwater management technologies are not exception. These are specifically important when markets are imperfect, because decisions are made based on households' own resources endowment. This suggests that households with more educated members are likely to have better access to information and are more aware about the merits and demerits of the technologies. They are also able to interpret

new information to make knowledge based decisions in favor of appropriate/suitable technologies. On the other hand, better educated households may be less likely to invest in labor-intensive technologies and practices, because they are more likely to earn higher returns from their labor and capital investment in other activities (M. Kassie et al., 2012; Pender and Gebremedhin 2007).

Household age may imply farming experience and ability to respond to unforeseen events/shocks. It may also imply that older household heads have probably a lifetime saving and accumulation of capital, and have respect in their community implying greater social capital. On the other hand, age can also be associated with loss of energy and short-planning horizons and reluctance towards new technologies due to risk aversion behavior.

Gender is an important factor in terms of access to resources. The general argument is that women have less access to important resources and services, such as land, labor, credit, education and are generally discriminated in terms of access to external inputs and information (De Groote, H. and Coulibaly, N., 1998; A.R. Quisumbing et al., 1995). In Sub-Saharan Africa, there are gender specific constraints that women face, such as less education, inadequate access to land, production assets and livestock ownership. It is obvious that these constraints have direct effect on technology adoption including rainwater management technologies where women are usually less likely to adopt, because these technologies are resources demanding and labor intensive (S. W. Ndiritu et al., 2011).

Capital ownership: This variable is peroxide by number of livestock in Tropical Units (TLU), farm size in adult equivalent and a dummy variable that capture whether or not a farm household owns land, and value of durable household asset. The assumption is that households who own

more capital are wealthier and more likely to take risks associated with adoption of new technologies. Moreover, such households are less liquidity constrained and are able to finance purchased inputs. We have also considered household expenditure as proxy of income level. Hence, the expected effect capita on the adoption rainwater management technologies is positive. However, since households with relatively larger land holdings may able to diversify their crops and income sources can be less susceptible to risks and shocks, they might be be less interested in investing in rainwater management technologies as a coping mechanism.

Off-farm activity: Economic incentives play an important role in the adoption of rainwater management technologies. Household access to off-farm employment and alternative sources of income, and the return from it is likely to influence the adoption rainwater management technologies in different ways. For example, those who have alternative sources of income are able to adopt technologies because they have better to finance investment in technologies. On the other hand, participation in off-farm income generating activities is likely to divert labor time from on-farm activities and working on rainwater management technologies both as private investment and collective action. The finding of Deressa et al. (2009) supports this hypothesis. Off-farm activity is captured by household members' participation in Food for Work program (FFW) and/or if any member of a household had migrated. Both variables are defined as dummy variable (equal to one, if participate one and zero if otherwise).

Access to Market, Extension, Credit and Input: Walking distance was used as a proxy of access to market, extension and credit services. Access to market can influence the use of input and access to information and support services. For example, Deressa et al. (2009) reviled that access to credit has positive and significant impact on the likelihood of using soil conservation,

changing planting dates, and using irrigation in the Blue Nile Basin. The hypothesis is, therefore, longer walking distance is the less likely that the household will adopt the technology.

Social capital: This captures variables, such as household's membership in informal institutions (such as, equib, edir). In Ethiopia, rural communities commonly form informal groups as labor sharing or saving mechanisms and risk sharing mechanisms. This can take pace in the form of friendship or kinship networks implying that households with more numbers of relatives and network are less likely to be exposed to risk and credit constraints; hence they are more likely to adopt technologies because they are in a better position to take risk (Fafchamps and Gubert 2007). With limited information and imperfect markets, social networks can facilitate the exchange of information enabling farmers to access inputs and overcome credit constraints. Social networks also reduce transaction costs and increase farmers' bargaining power, helping them to earn higher returns when marketing their products, which in turn can affect technology adoption (Pender and Gebremedhin 2007; Wollni et al. 2010; Lee 2005). Moreover, farmers who have limited contacts with extension agents can be informed about the methods and benefits of new technologies from their networks, as they share information and learn from each other. On the other hand, having more relatives may reduce incentives for hard-work and induce inefficiency, such that farmers may exert less effort to invest in technologies (M. Kassie et al., 2012). The expected effect of social capital coefficient is therefore ambiguous before empirically verified.

Biophysical Characteristics: Agricultural production in sub-Saharan Africa is characterized by wide variability of rainfall and temperatures. Certain rainwater management technologies can be adopted as a copping mechanism in low rainfall and moisture stress areas, while some of them

can be adopted because of high rainfall availability, so that to benefit from rainwater management for agricultural production. Unfavorable rainfall outcome, such as low rainfall may encourage farmers to adopt soil and water conservation structures. On the other hand, rainfall intensity that results in high runoff can augment soil erosion leading nutrient depletion. It can also increase water logging (Jansen et al. 2009; Kassie et al. 2010), which may negatively influence the likelihood of adoption of soil and water conservation. Hence, farm households may adopt certain rainwater management technologies (e.g., bunds/terraces) to reduce exposure to rainfall calamites by increasing soil moisture; reducing soil loss from erosion and flooding; and diversifying crop products.

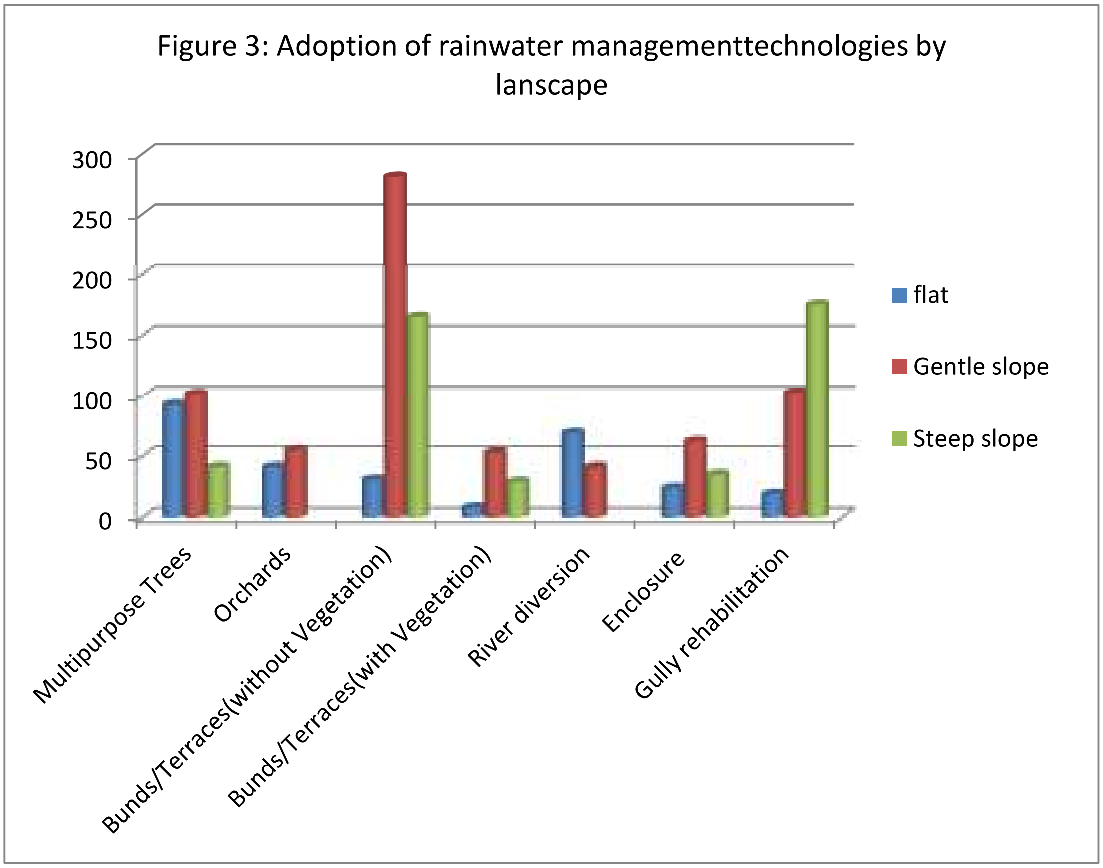
In the Blue Nile Basin, topography follows a gradient from flat lowlands in the West to mountainous area in the East (Pfeifer, C. et al., 2012). The same report indicated that most of the western Ethiopian highlands are dominated by Nitisols that is stable and relatively less prone to erosion, while the eastern part and highland plateau of the Blue Nile Basin are dominated by leptosols and vertisols, respectively. Leptosols are relatively shallow and prone to erosion while vertisols are low drainage heavy clay soils. This suggests that topographical and soil characteristics may affect the suitability of rainwater management technologies. Due to lack of site specific biophysical data, however, we considered district/wereda dummies assuming that such dummy variables can capture unobserved site biophysical and other differences.

5. Results and Discussion

5.1. Descriptive Results

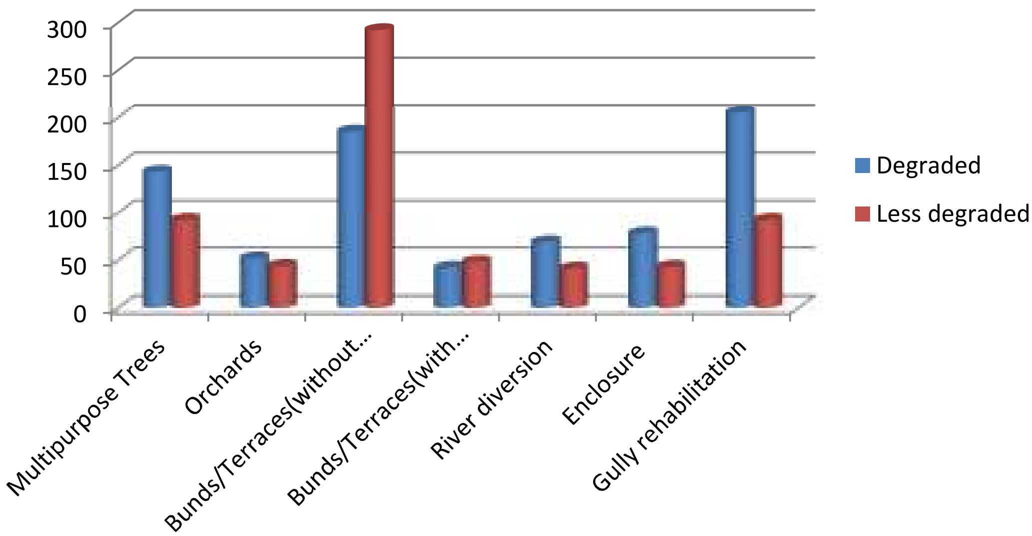
The suitability of rainwater management technology is likely to be influenced by land scape. Figure 3 shows that most of households' adoption of multipurpose trees, orchard, bunds/terrace

and area enclosure as rainwater management technologies were on gentle slope lands. On the other hand, river diversion and gully rehabilitation were suited on flat and steep slope lands, respectively.



The level of land degradation is also more likely to affect household's decision of rainwater management technology adoption. Based on our sample households' response, we observe that except bunds/terraces, most of the rainwater management technologies was adopted on degraded lands, probably suggesting that these technologies are used as ex-post land rehabilitation and resource conservation mechanisms (see Figure 4).

Figure 4: Land degradartion and adoptiontion of rainwater managementtechnologies



In addition to land scape and land degradation, the type of land use is likely to influence the suitability and adoption decisions of farm households. Accordingly, Figure 5 shows that multipurpose trees were adopted on crop and grass lands. Similarly, orchard and bund/terraces were adopted on both land use types despite that the rate of adoption seems to favor crop lands. Gully rehabilitation was more adopted on grass lands. Finally, our survey data evidenced that river diversion and area enclosure are more suited on crop and grass lands, respectively. Usually, since river diversion is used for irrigation and area enclosure for land conservation and natural resource regeneration, the result is not unexpected.

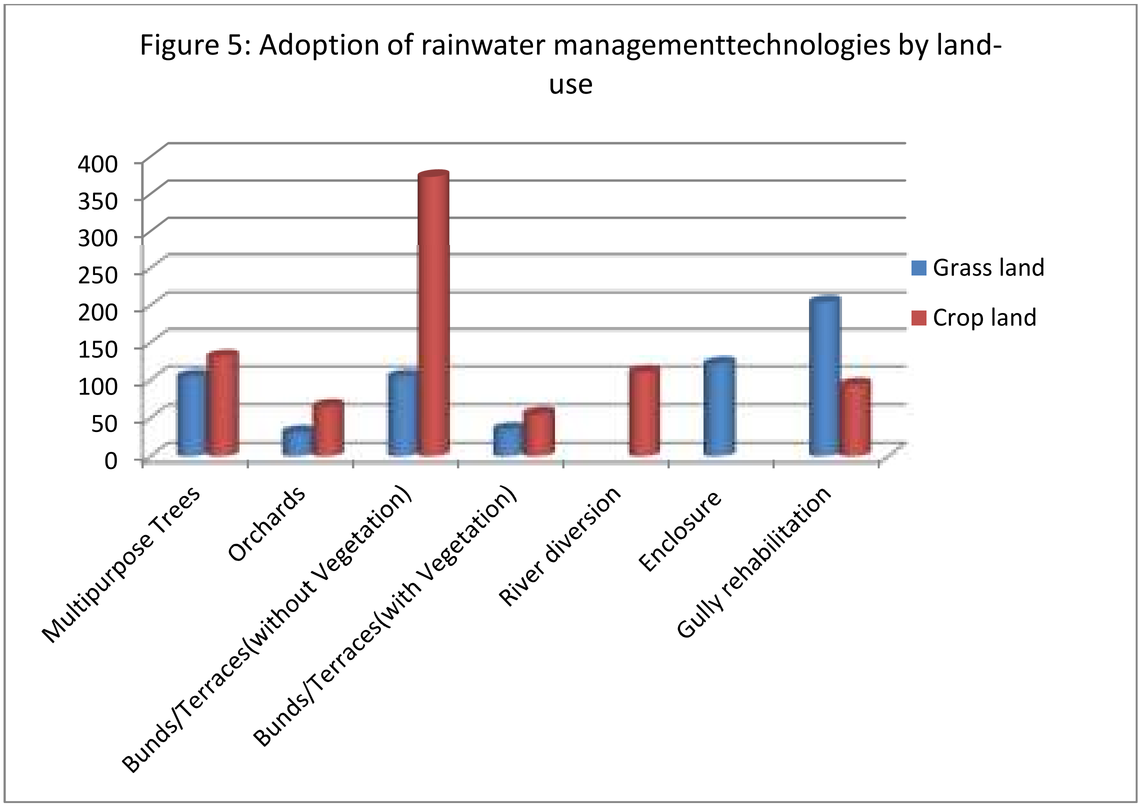


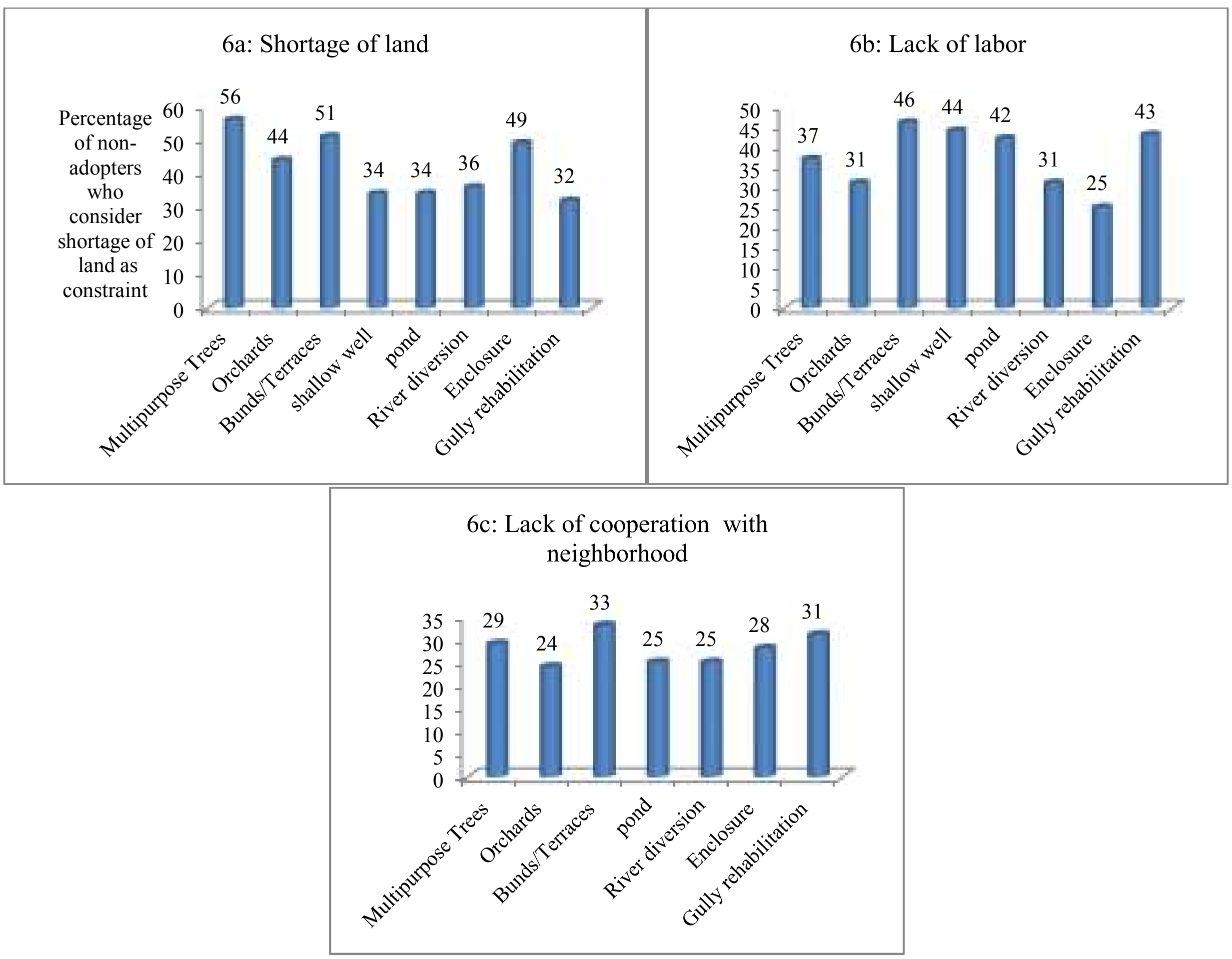
Table 6 presents definition and summary statistics of both dependent and independent variables used in this analysis. Accordingly, about 35 percent of sample households have practiced (adopted) multipurpose trees, while about 15, 72 and 56 percent of the sample households have adopted orchard, bunds/terraces and gully rehabilitation, respectively.

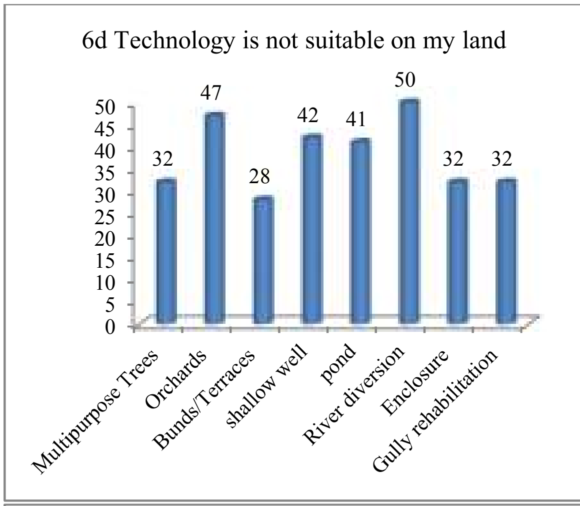
Table 6: Definition of variables and Descriptive statistics

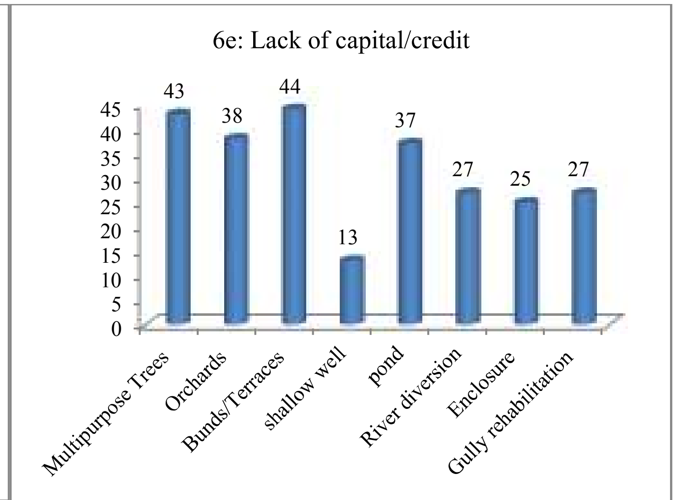
Variable description	Mean	Std. Dev.
Dependent Variables		
Multipurpose Trees (1=yes, 0=no)	0.353	0.478
Orchards(1=yes, 0=no)	0.146	0.354
Bunds/Terraces (1=yes, 0=no)	0.723	0.448
Gully rehabilitation(1=yes, 0=no)	0.550	0.498
Independent Variables		
Age of household head (years)	46.996	15.342
Gender of household head (1=male, 0=female)	0.846	0.361
Farming experience (years)	27.121	15.705
Marital status of household head (1=married, 0=single/separated/divorced)	0.838	0.369
Family size in adult equivalent (number)	4.684	2.073
Household head is educated or at least can read and write (1=yes, 0=no)	0.200	0.400
Number of household members with elementary (1-8) education level (number)	1.979	1.618
Number of household members with high school and above (>9) education level (number)	0.787	1.216
Participation in off-farm activity (1=yes, 0=no)	0.276	0.447
At least one household member has migrated (1=yes, 0=no)	0.133	0.339
Household's total expenditure during previous year (Birr)	2939.481	14538.610
Household's livestock holding in TLU (number)	5.234	4.612
Household own land (1=yes, 0=no)	1.002	0.723
Land holding per adult equivalent (ha)	0.428	0.399
One way walking distance to all weather road (minutes)	29.241	29.596
One way walking distance to wereda center (minutes)	47.076	36.354
One way walking distance to farmer training center (minutes)	35.408	27.626
One way walking distance to credit center(minutes)	47.375	39.422
Household participates in Debo (1=yes, 0=no)	0.890	0.313
Household participates in Equib(1=yes, 0=no)	0.125	0.331
Household participates in Edir(1=yes, 0=no)	0.925	0.285
Household member participates in women association(1=yes, 0=no)	0.201	0.401
Jedu district (wereda) (1=yes, 0=no) ***control wereda***	0.180	0.385
Guder district (wereda) (1=yes, 0=no)	0.320	0.467
Horro (Shambu) district (wereda) (1=yes, 0=no)	0.314	0.465
Diga district (wereda) (1=yes, 0=no)	0.314	0.465
Farta district (wereda) (1=yes, 0=no)	0.314	0.465
Gondar Zuria district (wereda) (1=yes, 0=no)	0.310	0.463
Fogera district (wereda) (1=yes, 0=no)	0.328	0.470

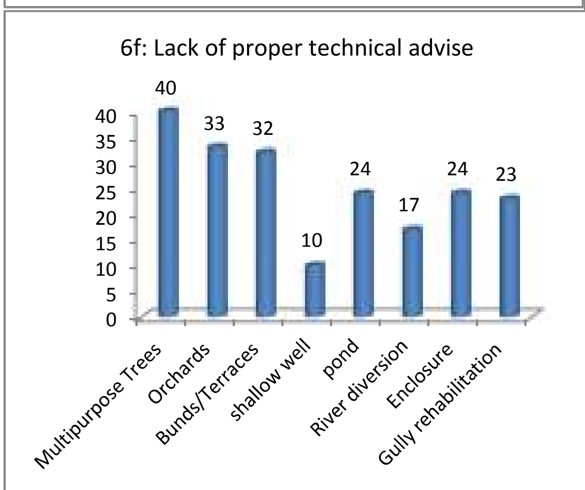
Descriptive results described above are based on the response of farm households who have already adopted some of the technologies, but these do not capture the perception of non-adopters and their limitations to invest and adopt the technologies. Figure 6 presents the perception of non-adopters' in relation to their most important constrains to invest in some of rainwater management technologies. This gives an insight why farmer households do not rainwater management technologies, while they are important to cope with moisture scarcity and improve livelihoods and can help to consciously address such constraints.

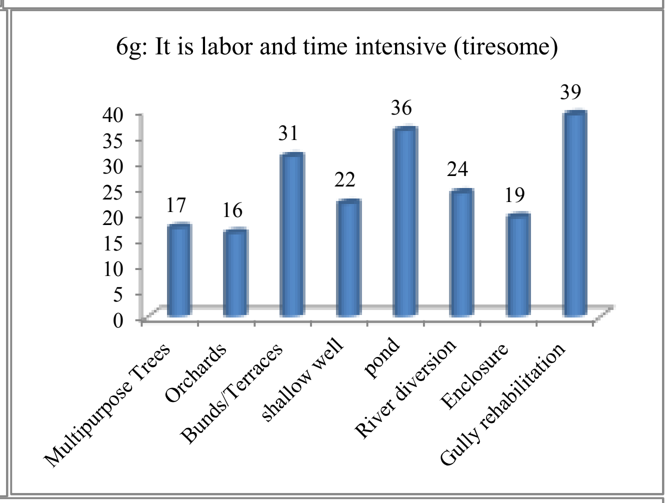
Figure 6: Reasons for not adopting rainwater management technologies: Frequency of farmers' response

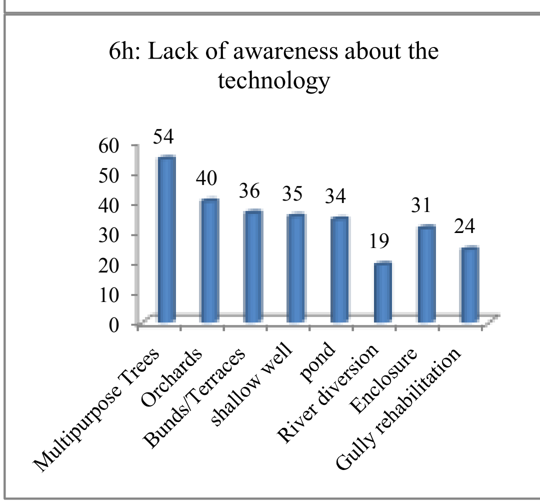


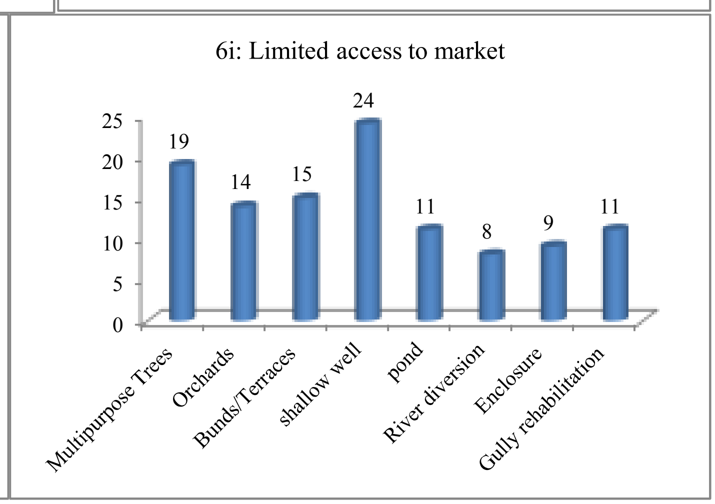

6d Technology is not suitable on my land
32
47
28
42
41
50
32
32
Multipurpose Trees
Orchards
Bunds/Terraces
shallow well
pond
River diversion
Enclosure
Gully rehabilitation


6e: Lack of capital/credit
43
38
44
13
37
27
25
27
Multipurpose Trees
Orchards
Bunds/Terraces
shallow well
pond
River diversion
Enclosure
Gully rehabilitation


6f: Lack of proper technical advise
40
33
32
10
24
17
24
23
Multipurpose Trees
Orchards
Bunds/Terraces
shallow well
pond
River diversion
Enclosure
Gully rehabilitation


6g: It is labor and time intensive (tiresome)
17
16
31
22
36
24
19
39
Multipurpose Trees
Orchards
Bunds/Terraces
shallow well
pond
River diversion
Enclosure
Gully rehabilitation


6h: Lack of awareness about the technology
54
40
36
35
34
19
31
24
Multipurpose Trees
Orchards
Bunds/Terraces
shallow well
pond
River diversion
Enclosure
Gully rehabilitation


6i: Limited access to market
19
14
15
24
11
8
9
11
Multipurpose Trees
Orchards
Bunds/Terraces
shallow well
pond
River diversion
Enclosure
Gully rehabilitation

5.2. Regression Results

The parameter estimates from the multivariate probit and the individual probit models are presented in Table 7 and annex A1, respectively. Despite that there is heterogeneity with regard to level of significance; the regression result suggest that the determinants of households' adoption decisions of rainwater management technologies can be broadly classified into household and socio-economic characteristics, access to market and services, social capital, and district specific characteristics.

The correlation coefficients that capture correlation across the rainwater management technology adoption equations are presented in Table 8. These coefficients are essentially pairwise correlations between the error terms in the system of equations of the multivariate probit model. With the exception of orchard and gully rehabilitation, all correlation coefficients are positive and significantly correlated supporting our hypothesis that the error terms in the rainwater management technology adoption equations are not independent to each other, hence a multivariate probit approach is appropriate in this case. A likelihood ratio test based on the log-likelihood values of the multivariate models also indicate significant joint correlations $\chi 2\ (6) = 36.324$ and probability $> \chi 2 = 0.000$ justifying that the estimation of the multivariate probit as opposed to separate univariate probit models and aggregating them into one equation model.

Furthermore, the positive and significant correlation coefficients of the error terms indicate that there is complementarity (positive correlation) between different rainwater management technologies being used by farmers, and supports the assumption of interdependence between the different rainwater management technology options. Another important point to note is that there

are substantial differences in the estimated coefficients across equations that support the appropriateness of differentiating between technology options. Social capital is unobservable asset, which is measured through the use of proxies. In this study, households' membership and participation in informal and formal community networks and associations (such as, debo, equib, and edir) and women association were used as proxies of social capital.

Household heads' age was found negatively and significantly correlated with the adoption of all rainwater management technologies (considered in this analysis). This indicates that older farmers are less likely to adopt rainwater management technologies as compared to younger farmers, possibly because young farmers are stronger to provide the required labor to work on the technologies. On the other hand, older farmers may have short planning horizon and are risk averse. Because of the risk aversion behavior, older farmers are commonly reluctant to adopt new technologies and they stick to traditional coppicing mechanisms, while younger farmers are more likely to try new innovations and take risk. They may also have longer planning horizon to justify investments in technologies whose benefits are realized over time

The result also reveals that male-headed households are more likely to adopt multipurpose trees as compared to female-headed households. While, this is in agreement with the findings of Adesina et al. (2000), M. Kassie et al. (2009) reported that female-headed households are more likely to adopt sustainable agricultural technologies. This suggests that since impact of gender on technology adoption is likely to be technology-specific, there is no need to generalize about the impact of gender on technology adoption. In our case, however, it seems that male-headed households have a comparative advantage in rainwater management technologies. For example,

Figure 6 shows the proportion male and female headed households who have adopted rainwater management technologies.

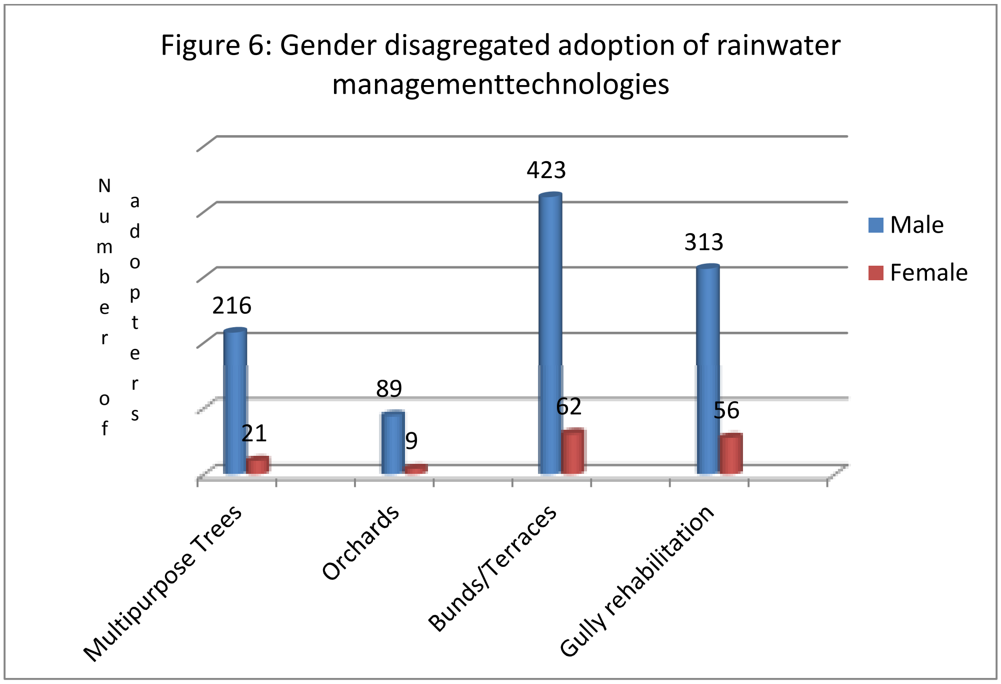


Figure 6: Gender disagregated adoption of rainwater managementtechnologies

The possible explanation for such skewed observation could be in most rural farming communities in Ethiopia, much of an agricultural work is done by male, whereas women are usually restricted to household and backyard activities. Since men do much of the agricultural work, they are more likely to have better farming experience and ability to respond to unforeseen climatic shocks and other events. Farming experience usually increases the probability of adoption of technologies, because experienced farmers are likely to have more information and knowledge on changes in climatic conditions and coping mechanisms. The important policy message of this is that targeting women groups to address their constraints to actively participate in rural economic activities can have significant impacts to increase the adoption of rainwater management technologies by smallholder farmers. Furthermore, farmers with better experience are usually progressive and role models and can be targeted in promoting the technologies,

making use of such successful lead farmers as entry points in promoting the adoption of rainwater management technologies among smallholder farmers can have significant positive effect.

Marital status (defined as equal to 1 if married and 0 if single/separated/divorced) was negatively correlated with adoption of multipurpose trees, but we do not have sufficient explanation for this. As expected, family size in adult equivalent has a positive and significant effect on the adoption of multipurpose trees and orchard. This possibly implies that the technologies are labor intensive; therefore, households who own more labor are more likely to adopt them. Participation in off-activity has negative and significant effect on the adoption of gully rehabilitation, and migration on the adoption of orchard and bund/terraces. The implication is that both off-farm and migration are likely to compute for labor than their contribution to household liquidity improvements, which in turn could have been used to finance investment in rainwater management technologies.

Ownership of livestock has positive impact on the adoption of rainwater management technologies, but it is statistically significant in relation to orchard and bund/terraces. The implication is that wealth positively affects the likelihood of adoption decisions, because wealthier farmers are likely have better access to resources and are in a better position to take risks related to technologies. On the other hand, ownership of land is positively correlated with adoption of multipurpose trees and orchard, but negatively correlated with bund/terraces. The intuition of this result is that farmers with high land ownership are likely to be less resource constrained and have better option to diversify their income and have less incentive to invest in bund/terrace, probably due to its labor and land intensive nature. Moreover, comparing the

technologies, bund/terrace and gully rehabilitation are more likely to be a collective action activities, possible with payment (such as FFW) both on private or common land. Wile, multipurpose trees and orchard are more of private investments, hence, those who own more land are more likely to defect collective action as they may not expect to benefit from FFW payment. The implication is that it is important for the government to ensure tenure arrangements and facilitate investments in long-term rainwater management technologies, because tenure arrangements can increase farmers' confidence and is an incentive in facilitating their investment even in the communal land holding system. Given the fact that the benefits from investing in resource conservation and environmental rehabilitation accrue over time and implies that secure land tenure will impact adoption decisions positively.

As expected, access to market, farmer training (extension) center and credit captured by walking time to the nearest center were found to negatively affect the adoption of rainwater management technologies although some of the results were not statistically insignificant (see Table 7). The message from this result is that improved access to market, extension services and credit increases the probability of adoption of rainwater management technologies. Farmers who have better extension contacts have greater chances to be aware of changing climatic conditions and the benefits from adoption of rainwater management technologies. Hence, the policy implication is improving farmers' access to extension services has a potential of increased farmers' awareness how to manage and use rainwater as a response to climatic shocks. Furthermore, access to credit and markets have higher adoption rate, because access to affordable credit increases financial capacity of farmers and ability to meet liquidity constraints associated with rainwater management technology they might want to adopt and scale-up.

The decision to participate in social networks (group membership) was defined as binary (equal to one if the household participate, and zero if not). The regression result suggested that social capital (households' membership in group networks) conditions households' decision to adopt rainwater management technologies. For example, households' membership in debo (traditional labor sharing system) has positive and significant effect on adoption probability of budd/terraces and gully rehabilitation. Similarly, households' participation in edir (traditional peer support system) affects (positively and significantly) the adoption of orchard and bud/terrace. Membership in women association also has positive and significant effect on of multipurpose trees and orchard. Women associations commonly play the role of facilitating access to affordable (low interest rate) credits and technologies to their members. In general, the result suggest that social networks (both formal and informal) help members to pull the support of group mates to overcome labor and/or credit constraints.

Wereda fixed effects were included to capture unobserved site specific factors that can affect the probability of adoption of rainwater management technologies. Results show that farm households in Guder wereda are less likely to adopt orchard, bund/terrace and gully rehabilitation than farm households in Jeldu. Farm households in Horro (shambu), and Diga are more likely to adopt multipurpose trees, but less likely to adopt bund/terrace and gully rehabilitation than those in Jeldu wereda (the control wereda). We also found that the probability of adoption of orchard in Diga and Farta weredas, and gully rehabilitation in Farta and Gondar-Zuria weredas are higher than in Jeldu wereda. Finally, our result indicate that the adoption of multipurpose trees in Gondar-Zuria and Fogera; adoption of bund/terraces in Fogera is less likely as compared with Jeldu.

Results discussed above are for the parameter estimates from the multivariate probit approach. For comparison, we have reported the parameter estimates from individual probit estimation in A1. In general, the signs and significant variables in both approaches are fairly similar. However, note that the multivariate probit approach allows us to simultaneously estimate interdependent equation, while the covariance is correlated which is not possible in the individual probit models. In general, both the descriptive and regression results suggest that it might be important to examine the socio-economic and demographic characteristics of households, and biophysical suitability instead of promoting blanket recommendations for the adoption of rainwater management technologies.

Table 7: Results of the Multivariate Probit Model

Independent Variables	Technologies (Dependent Variables)			
	Multipurpose trees	Orchard	Bund/Terraces	Gully rehabilitation
	Coefficient	Coefficient	Coefficient	Coefficient
Household characteristics and asset holding				
Household head age (years)	-0.011***(-0.004)	-0.018***(-0.006)	-0.013***(-0.005)	-0.0122***(-0.004)
Household head's gender (1=male)	0.760***(-0.221)	0.379(-0.312)	0.159(-0.233)	0.056(-0.214)
Household head's marital status (1=married)	-0.555***(-0.202)	-0.242(-0.291)	0.202(-0.214)	-0.0725(-0.211)
Family size in adult equivalent	0.147***(-0.043)	0.213***(-0.054)	0.024(-0.052)	0.040(-0.044)
Household head is educated (1=yes)	0.175(-0.154)	-0.016(-0.185)	0.122(-0.169)	0.0306(-0.150)
Number household members with elementary (1-8) education level	-0.032(-0.046)	-0.001(-0.059)	0.035(-0.054)	0.036(-0.045)
Number household members with high school and above (>8) education level	-0.018(-0.058)	-0.014(-0.075)	-0.080(-0.066)	-0.012(-0.058)
At least one household member participate in off-farm activity (1=yes)	0.172(-0.135)	-0.232(-0.181)	-0.070(-0.153)	-0.281**(-0.136)
At least one household member migrates (1=yes)	-0.267(-0.188)	-0.541**(-0.272)	-0.436**(-0.209)	0.015(-0.187)
Households' total expenditure during previous year	0.001(0.001)	0.001(0.001)	0.001(-0.001)	0.001(0.001)
Livestock holding in TLU	0.015(-0.015)	0.031(-0.018)	0.050***(-0.018)	0.003(-0.015)
Land holding per adult equivalent	0.363**(-0.167)	0.559***(-0.196)	-0.395**(-0.174)	-0.145(-0.169)
Household own of land (1=yes, 0=no)	0.179(-0.144)	0.120**(-0.054)	0.516(-0.348)	-0.313(-0.409)
Access to market and services				
One way walking distance to all weather road (minutes)	0.002(-0.002)	-0.006(-0.003)**	-0.001(-0.002)	-0.004*(-0.002)
One way walking distance to wereda center (minutes)	0.001(-0.002)	-0.006***(-0.002)	0.003(-0.002)	-0.012(-0.002)
One way walking distance to FTC (minutes)	-0.001(-0.002)	0.001(-0.003)	0.001(-0.002)	-0.001(-0.002)
One way walking distance to credit center (minutes)	-0.003(-0.002)	0.003*(-0.002)	0.001(-0.002)	0.002(-0.002)
Indicators of social capital				
Household participate in Debo (1=yes)	-0.112(-0.197)	0.411(-0.304)	0.521***(-0.194)	0.371*(-0.204)
Household participate in Equib (1=yes)	-0.193(-0.169)	0.065(-0.230)	-0.262(-0.188)	0.170(-0.171)
Household participate in Edir (1=yes)	0.253(-0.275)	0.987***(-0.310)	0.491**(-0.246)	0.057(-0.223)
Household participate in women association (1=yes)	0.531***(-0.140)	0.408**(-0.186)	-0.030(-0.165)	0.038(-0.141)
District (Wereda) dummies				
Woreda is Guder (1=yes, 0=no)	0.243(-0.153)	-2.003***(-0.378)	-0.928***(-0.168)	-0.608***(-0.150)
Woreda is Horro (Shambu) (1=yes, 0=no)	0.282*(-0.161)	-0.404*(-0.224)	-0.892***(-0.185)	-0.369**(-0.158)
Woreda is Diga (1=yes, 0=no)	0.411***(-0.145)	0.505***(-0.196)	-0.624***(-0.185)	-1.044***(-0.156)
Woreda is Farta (1=yes, 0=no)	-0.211(-0.179)	0.808***(-0.248)	-0.133(-0.215)	0.795***(-0.172)
Woreda is Gonder zuria (1=yes, 0=no)	-0.454***(-0.173)	-0.177(-0.236)	-0.037(-0.209)	1.053***(-0.188)
Woreda is Fogera (1=yes, 0=no)	-0.690***(-0.161)	-0.093(-0.230)	-0.327**(-0.163)	0.063(-0.140)

Omitted (control) werda is Jeldu	-	-	-	-
Constant	-1.226***(-0.441)	-2.952***(-0.566)	0.207(-0.479)	0.632(-0.526)
Regression Diagnostics				
Number of observation	654			
LR Test of rho=0: χ^2 (6)	36. 324***			
Wald (χ^2)	773.730			
Log pseudolikelihood	-1108.127			
Prob > χ^2	0.000***			

*Note: *, **, *** significant at 10%, 5% and 1%, respectively. Figures in parenthesis are robust standard errors*

Table 8: Technology relationships from Multivariate Probit Regression Equations (Robust standard error in parentheses)

Rainwater Management Technology	Multipurpose trees	Orchard	Bund/Terraces
Orchard	ρ_{21} 0.448***(0.080)		
Bund/Terraces	ρ_{31} 0.154*(0.084)	ρ_{32} 0.232***(0.085)	
Gully rehabilitation	ρ_{41} 0.127*(0.069)	ρ_{42} - 0.006(0.076)	ρ_{43} 0.156**(0.071)

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Annex:

A1: Probit parameter estimates

Independent Variables	Rainwater Management Technologies			
	Multipurpose trees	Orchard	Bund/terrace	Gully rehabilitation
	Coef.	Coef.	Coef.	Coef.
Age	-0.009	-0.007	-0.017**	-0.015**
	(0.007)	(0.010)	(0.007)	(0.006)
Sex	0.716***	0.420	0.156	0.102
	(0.223)	(0.298)	(0.244)	(0.210)
Experience	-0.004	-0.012	0.005	0.003
	(0.006)	(0.009)	(0.007)	(0.006)
Maritalsta~s	-0.573***	-0.329	0.209	-0.058
	(0.206)	(0.277)	(0.224)	(0.207)
Adultequiv~t	0.147***	0.214***	0.039	0.033
	(0.043)	(0.053)	(0.051)	(0.044)
Eduredwrite	0.190	0.090	0.111	0.014
	(0.153)	(0.185)	(0.169)	(0.149)
NOelementary	-0.032	0.020	0.023	0.043
	(0.046)	(0.059)	(0.053)	(0.044)
NOhigschab~e	-0.010	0.002	-0.076	-0.018
	(0.057)	(0.073)	(0.065)	(0.057)
Offarm	0.149	-0.251	-0.078	-0.268**
	(0.135)	(0.182)	(0.154)	(0.135)
migrate	-0.312	-0.594**	-0.404*	0.025
	(0.194)	(0.271)	(0.213)	(0.188)
totlexpend	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
TotalTLU	0.010	0.027	0.053***	0.005
	(0.015)	(0.019)	(0.018)	(0.015)
landholhap~i	0.388**	0.578***	-0.342**	-0.199
	(0.177)	(0.198)	(0.166)	(0.173)
DistanceAl~d	0.002	-0.005	-0.001	-0.003
	(0.002)	(0.003)	(0.002)	(0.002)
DistanceMa~a	0.000	-0.006***	0.003	0.000
	(0.002)	(0.002)	(0.002)	(0.002)
DistanceFa~e	-0.001	0.000	0.002	-0.001
	(0.002)	(0.003)	(0.002)	(0.002)
DistanceCr~e	-0.002	0.003*	0.001	0.000
	(0.002)	(0.002)	(0.002)	(0.002)
Debo	-4.721***	0.111	0.024	0.716
	(0.338)	(0.309)	(0.541)	(0.599)

Equib	-0.199 (0.169)	0.144 (0.238)	-0.252 (0.188)	0.183 (0.171)
Edir	0.206 (0.275)	0.921*** (0.321)	0.556** (0.273)	0.072 (0.223)
Mehber	0.267* (0.141)	-0.262 (0.175)	-0.109 (0.153)	-0.057 (0.131)
womenassoc	0.493*** (0.143)	0.442** (0.192)	0.011 (0.171)	0.041 (0.142)
labourexchan	4.630*** (0.279)	0.348 (0.316)	0.527 (0.534)	-0.430 (0.579)
woreda2	0.239 (0.152)	-2.035*** (0.413)	-0.935*** (0.169)	-0.591*** (0.151)
woreda3	0.332** (0.168)	-0.509** (0.232)	-0.943*** (0.197)	-0.377** (0.163)
woreda4	0.571*** (0.166)	0.327 (0.211)	-0.697*** (0.205)	-1.067*** (0.175)
woreda5	-0.269 (0.187)	0.860*** (0.261)	-0.106 (0.213)	0.771*** (0.176)
woreda6	-0.493*** (0.174)	-0.109 (0.244)	-0.023 (0.221)	1.067*** (0.190)
woreda7	-0.670*** (0.159)	-0.074 (0.230)	-0.335** (0.166)	0.048 (0.140)
_cons	-1.156*** (0.422)	-2.773*** (0.566)	0.644 (0.410)	0.448 (0.387)
Number of observation	654	654	654	654
Log pseudolikelihood	-337.567	-181.143	-241.263	-364.5391
Wald chi2(29)	572.13	128.40	223.74	141.62
Pseudo R2	19%	30%	38%	0.1924
Prob > chi2	0.000	0.000	0.000	0.000

A2: Adoption of rainwater management technologies and ownership of land, slope, degradation and land use

Water ManagementTechnology	Ownership		Slope			Degradation		Land use	
	Public land	Private land	flat	Gentle slope	Steep slope	Degraded	Less degraded	Grass land	Crop land
Multipurpose Trees	36	201	92	102	41	143	92	104	131
Orchards		98	41	55		52	44	31	65
Bunds/Terraces(without Vegetation)	45	322	31	281	165	185	292	104	373
Bunds/Terraces(with Vegetation)	21	44	8	53	29	42	48	35	55
Shallow/hand-dug wells		33							
Pond	1	22							
River diversion	85	27	69	41		69	41		110
Enclosure	101	29	24	62	35	78	43	121	
Gully rehabilitation	18	278	19	103	175	205	92	204	93
Total	411	878	284	697	445	774	652	599	827

A3: Gender disaggregated adoption of rainwater management technologies

Rainwater management technologies	Male		Female		Total	*T-test (Significance of difference)*
	number	mean	number	mean		
Multipurpose Trees	216	0.380 (0.486)	21	0.204 (0.405)	237	0.000***
Orchards	89	0.157 (0.364)	9	0.087 (0.284)	98	0.066*
Bunds/Terraces(without Vegetation)	423	0.745 (0.436)	62	0.602 (0.492)	485	0.003***
Gully rehabilitation	313	0.551 (0.498)	56	0.544 (0.501)	369	0.890
Total	1380		198		1578	

*Figures in parenthesis are standard deviations, *, **, *** at 10%, 5%and 1% significance level, respectively.*

A4: Biophysical Characteristics by Wereda and Watershed

Woreda	Sample watershed	Nearest Rainfall and temperature station	Mean Aridity Index(AI)	***Erosion rate/ton/ha/yr	Travel time to nearest town /hr/Mean	CV	Temperature	Soil type	Land-use type
Gonder Zuria	Gumara/Maksenit	Gondar	0.66	-7.65 low/tolerable	1.8	0.298	27	Chromic Luvisols & Eutric Leptosols	Agriculture & Agropastoral
Fogera	Mizwa	Worota/Addis zemen	0.64	-19.17 low/tolerable	3.2	0.348	29	Haplic Luvisols &Eutric Fluvisols	Agriculture& Agro_pastoral
Farta	Zefe	Debretabor	0.81	-27.5 low/tolerable	4.46	0.316	22	Chromic Luvisols	Agriculture
Diga	Diga/Dapo	Nekemte	1.01	-13.8 low/tolerable	3.7	0.305	24	Haplic Alisols	Sylvo_pastoral & Agro_sylvicultural
Horo	Laku	Shambu	1.03	- 16.39 low/tolerable	5.7	0.328	22	Haplic Alisols	Agro_pastoral
Jeldu	Meja/Jeldu	Ambo	0.67	-4.23 low/tolerable	6.4	0.854	23	Haplic Alisols	Agriculture
Guder	Boke/Gorosole	Tikur Inchini	0.7	- 31.77 low/tolerable	5	0.228	23	Chromic Luvisols	Agro_pastoral
Source			http://www.cgiar-csi.org	Haileslassie et al. 2005	http://maps.worldbank.org/overlays/7406	NMA		MoWR	MoWR

Note: <11, 11 to 15 and >15 ton/ha/year; roughly classified as: low/tolerable, medium and critical/high erosion rate, respectively.

A5: Reasons for not adopting rainwater management technologies: Frequency of farmers' response

	Multipurpose Trees	Orchards	Bunds/Terraces (without Vegetation)	Bunds/Terraces (with Vegetation)	shallow well	pond	River diversion	Enclosure	Gully rehabilitation
No problem of land degradation	19	11	23	9	10	9	13	13	18
Availability of sufficient rainfall	12	10	15	5	17	13	15	8	10
Have enough land	17	18	18	7	15	14	13	17	14
Have no enough land	56	44	51	20	34	34	36	49	32
Lack of labor	37	31	46	17	44	42	31	25	43
It is labor and time intensive (tiresome)	17	16	31	12	22	36	24	19	39
Availability of sufficient surface/ground water	14	13	11	5	28	18	16	8	9
Lack of awareness about the technology	54	40	36	12	35	34	19	31	24
Technology is not suitable on my land	32	47	28	10	42	41	50	32	32
Lack of capital/credit	43	38	44	16	13	37	27	25	27
Not profitable to invest	12	15	17	5	23	15	9	14	14
Lack of proper technical advise	40	33	32	11	10	24	17	24	23
I have better options	6	7	8	3	13	8	7	7	7
Limited access to market	19	14	15	5	24	11	8	9	11
Lack of cooperation with neighborhood	29	24	33	12	NA	25	25	28	31